

HYSPLIT Nuclear Applications and Emergency Response

Presenter: Tianfeng Chai

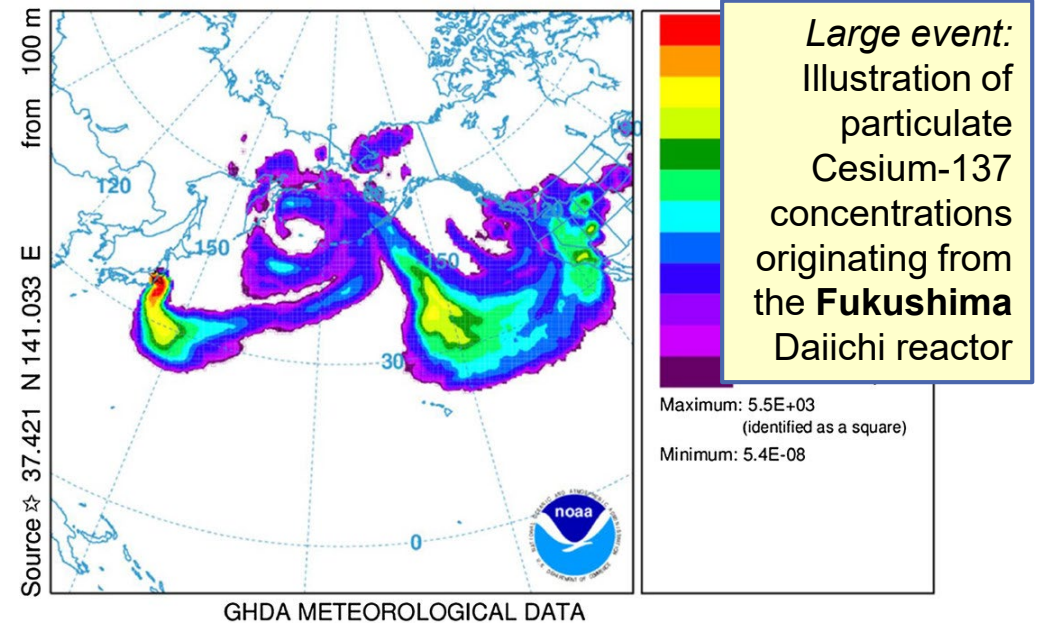
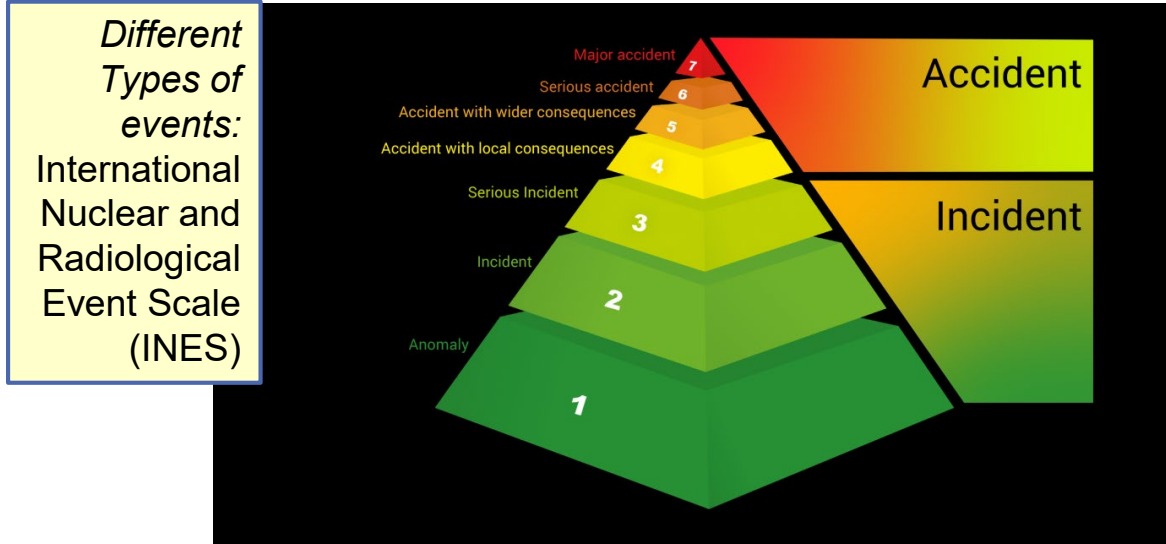
Other Team Members: Alice Crawford, Hyun-Cheol Kim, Mark Cohen

NOAA Air Resources Laboratory

March 2022



HYSPLIT Nuclear Applications and Emergence Response



Relevance to NOAA mission

Make forecasts better

Improving HYSPLIT models, meteorological inputs, and emissions

← → C ready.noaa.gov/index.php

- HYSPLIT Model
- READY >>
 - READY News
 - Transport & Dispersion
 - Get/Run HYSPLIT
 - HYSPLIT Tutorials
 - HYSPLIT Forum
 - HYSPLIT Workshop
 - Volcanic Ash
 - Fukushima TCM
 - Short-Range Ensemble Dispersion Forecasts
 - Balloon Flight Forecasting Tools
 - Locusts
 - DATUM Tracer Verification
 - HYSPLIT Modeling Group
 - Current & Forecast Meteorology
 - North America
 - Animations
 - Web API
 - Archived Meteorology
 - North America
 - Air Quality
 - U.S. Trajectories
 - Smoke Forecast Verification
 - Emergency Assistance
 - RSMC Products
 - RSMC Information
 - Internal Use Only

READY Real-time Environmental Applications and Display sYstem

READY (Real-time Environmental Applications and Display sYstem) has been developed to allow users to access and display meteorological data products and to run the HYSPLIT transport and dispersion model on the NOAA Air Resources Laboratory's (ARL) web server. READY brings together dispersion models, meteorological display programs and textual weather forecast programs generated over many years at ARL into a form that is easy to use by anyone. Its primary user group, however, is atmospheric scientists.

A research paper providing an overview of READY titled "Real-time Environmental Applications and Display sYstem: READY" is now available. Any research papers published using READY products should include a reference to this paper.

Emergency Assistance

QUICK HYSPLIT MODEL
Concentration: 1 milligram averaged between 0 m and 500 m
Integrated from 1800 17 Mar to 0000 18 Mar 11 (UTC)
Cape Release started at 1800 17 Mar 11 (UTC)

GHDA METEOROLOGICAL DATA

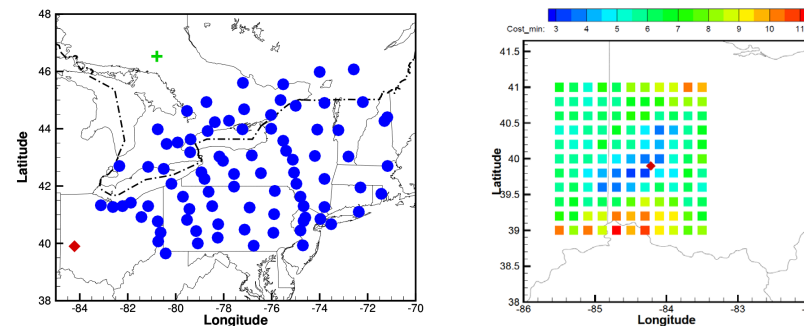
Share knowledge and information with others

Working with many other int'l & national agencies / organizations for nuclear emergency preparedness and response



Drive Innovative Science

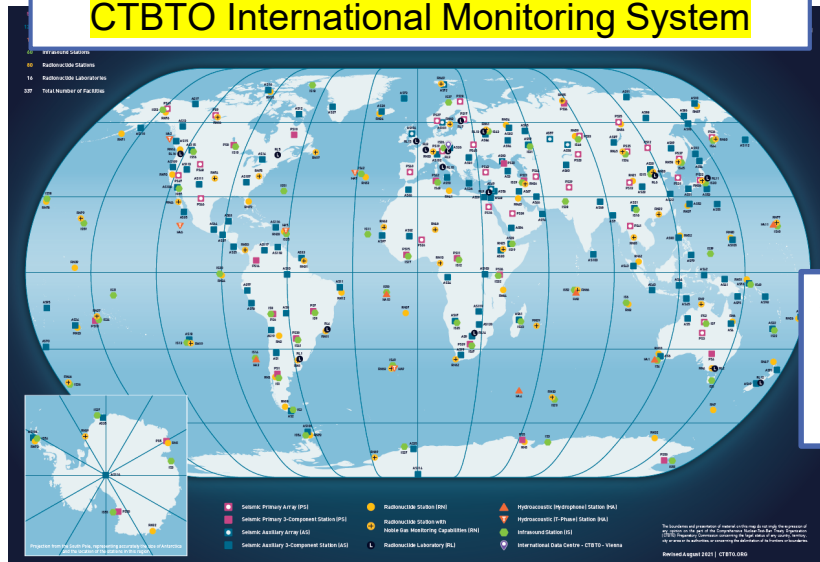
Developing Transfer Coefficient Matrix (TCM) approach, and exploring various inverse modeling techniques to utilize measurements to estimate unknown emissions




Chai et al., 2018

NOAA Backtracking support to Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) using HYSPLIT (On-demand Operation)

CTBTO International Monitoring System



NOAA Backtracking Support to CTBTO using HYSPLIT



Parsing email request and generate HYSPLIT control

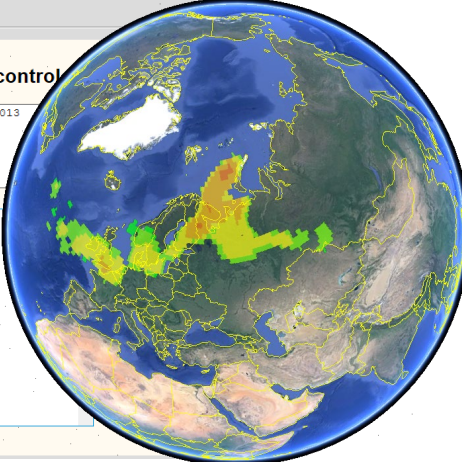
Processing request.20130411_1897 at Thu Apr 11 14:37:20 EDT 2013
 Parsing request email ...
 Control files generated!
 completed simulations at Thu Apr 11 14:37:20 EDT 2013

Station	Display control file for the selected station
Station 1	06
Station 2	
Station 3	
Station 4	
Station 5	89.08 1.0
Station 6	89.08 30.0
Station 7	

```

10000.0
4
/pub/archives/gdas1/
current:7days
/pub/archives/gdas1/
gdas1.apr13.w1
/pub/archives/gdas1/
gdas1.mar13.w5
/pub/archives/gdas1/
gdas1.mar13.w4
                    
```

Run HYSPLIT DISPERSION MODEL



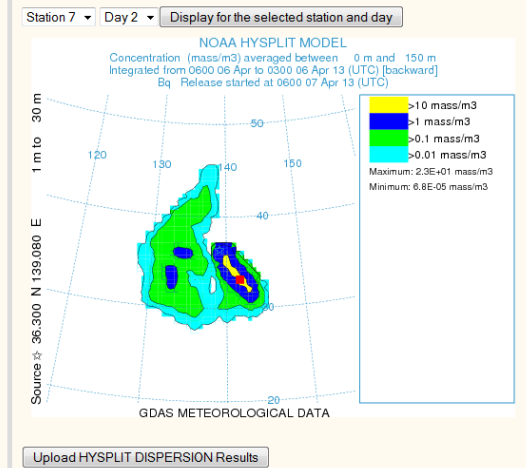
- Display CTBO request email:
- Create control files & RUN:
- HYSPLIT run status & PLOT:
- Dispersion plots & Upload:

- ARL developed HYSPLIT-based software for on-demand provision of backtracking support to CTBTO
- Operational at NOAA/NCEP since 2014.
- CTBTO sends a request when one or more of its 80 radionuclide stations detect high air concentrations.
- Backward dispersion results are sent back to CTBTO for source term estimation (location and strength).
- ARL has continuously provided support and updates to this on-demand operation.



- Display CTBO request email:
- Create control files & RUN:
- HYSPLIT run status & PLOT:
- Dispersion plots & Upload:

HYSPLIT backward dispersion run from CTBTO stations

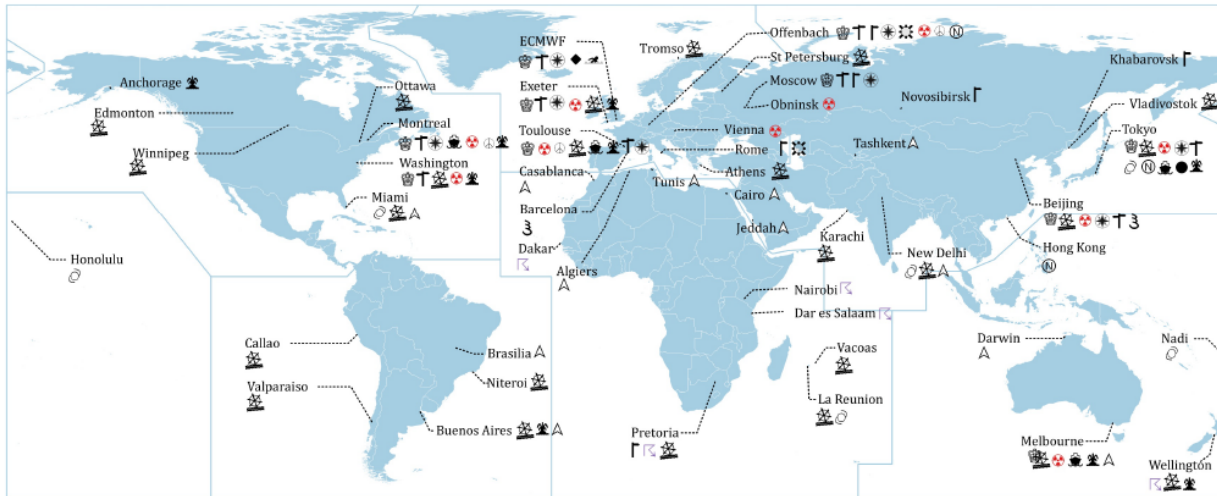


WMO's RSMC Emergency Response Activities (ERA)

WMO Designated Global Data-processing and Forecasting System Centres

- Nowcasting to medium-range prediction

Updated on 22 July 2021



Legend (The number in parenthesis indicates the number of designated Centres)

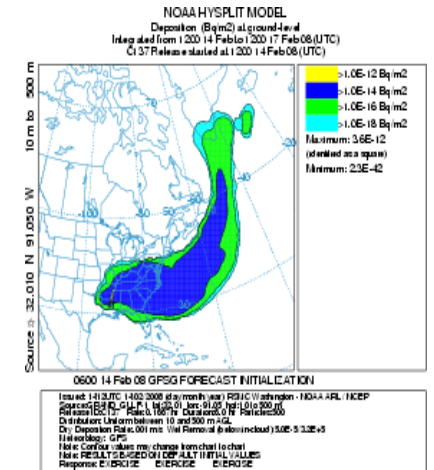
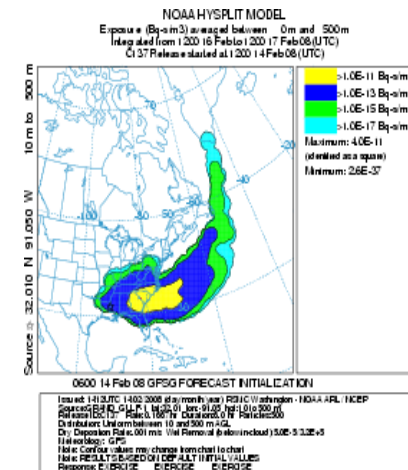
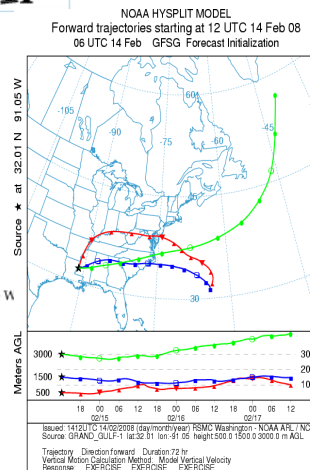
- | | | |
|--|--|--|
| ☉ World Meteorological Centre (WMC) (10) | 🌊 RSMC Numerical Ocean Wave Prediction (4) | ☄ RSMC Sand and Duststorm Forecasts (2) |
| ⚓ RSMC ^o Geographic Specialization (12) | 🕒 RSMC Nowcasting (3) | ☄ ICAO designated Volcanic Ash Advisory Centres (9) |
| ⚡ RSMC Global Deterministic NWP** (9) | 🌪 RSMC Regional Severe Weather Forecasting (5) | 🌊 RSMC Marine Meteorological Services (24) |
| 🌪 RSMC Global Ensemble NWP (8) | 🌀 RSMC Tropical Cyclone Forecasting (6) | ◆ Lead Centre for Deterministic NWP Verification (1) |
| ⌛ RSMC Limited-Area Deterministic NWP (6) | ☢ RSMC Nuclear Emergency Response (10) | ● Lead Centre for EPS Verification (1) |
| ⌛ RSMC Limited-Area Ensemble NWP (2) | ☢ RSMC Non-Nuclear Emergency Response (3) | ⚓ Lead Centre for Wave Forecast Verification (1) |

* RSMC stands for Regional Specialized Meteorological Centre
** NWP stands for Numerical Weather Prediction

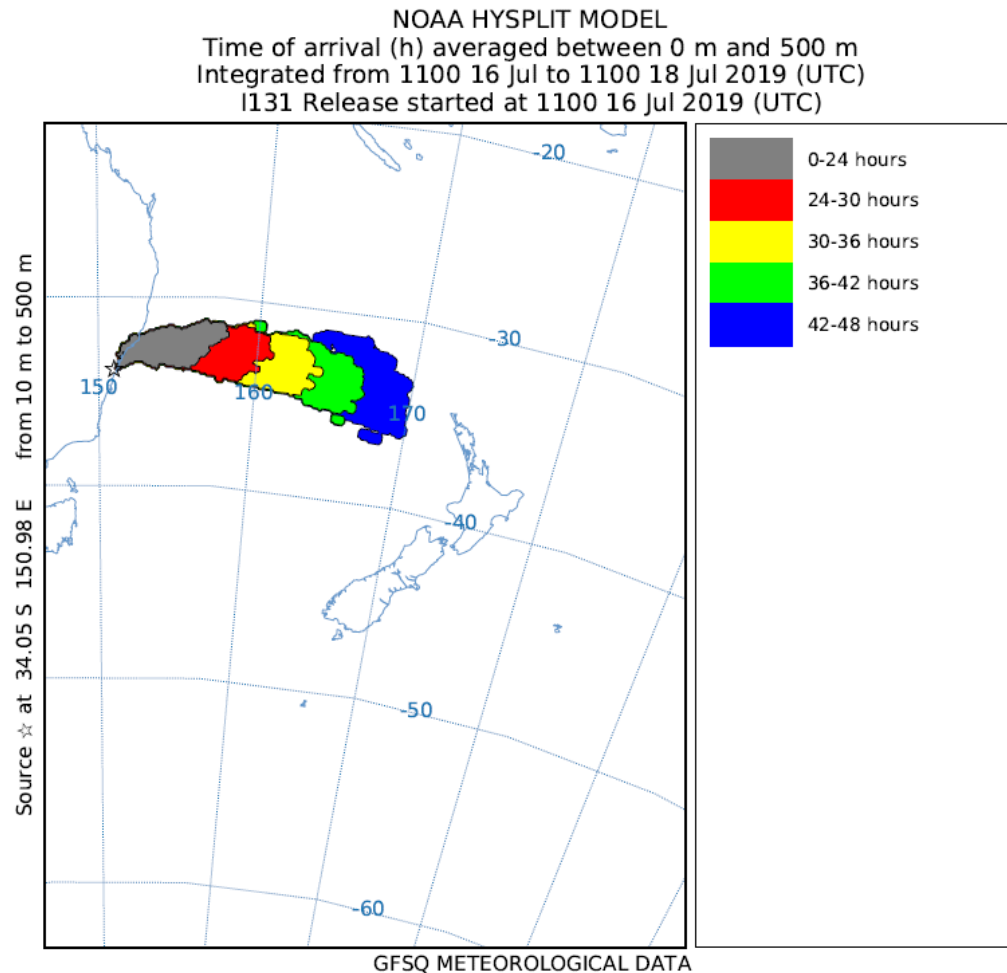
Disclaimer
The depiction and use of boundaries, geographic names and related data shown on maps are not warranted to be error free nor do they necessarily imply official endorsement or acceptance by the WMO

☢ There are a total of 10 Regional Specialized Meteorological Centres (RSMCs) designated by WMO for Nuclear Emergency Response.

- ARL, together with NOAA NWS NCEP, are designated by the WMO as the Washington Regional Specialized Meteorological Centre (RSMC), one of ten worldwide RSMCs for emergency environmental response related to potential radionuclide sources.
- Beginning in 1993 and formalized in 2007, ARL has been performing routine monthly forecast exercises with other RSMC partners and the International Atomic Energy Agency (IAEA), including transferring forecasting results to and from all the other centers.



Time of Arrival (ToA) and Transfer Coefficient Matrix (TCM) Products



- **ToA (Expected to be operational in 2022)**

- The code to calculate the pollutant Time of Arrival and a Python program for plotting ToAs have been developed.

- **TCM (under development)**

- The simulation is divided into smaller time segments and each segment is an independent calculation using a unit source emission.
- The set of calculations for all emission times is defined as the Transfer Coefficient Matrix (TCM).
- When quantitative results are required, the actual air concentrations and depositions are computed in a simple post-processing step by multiplying the TCM by the appropriate time-varying emission rates and radioactive decay constant for each relevant radionuclide.
- Allows updated forecasts to be quickly produced when new emissions estimates are made available

Implement Transfer Coefficient Matrix (TCM) Approach in Radionuclide Transport and Dispersion Forecasting – Ongoing



By Zachary Cohen, CNN

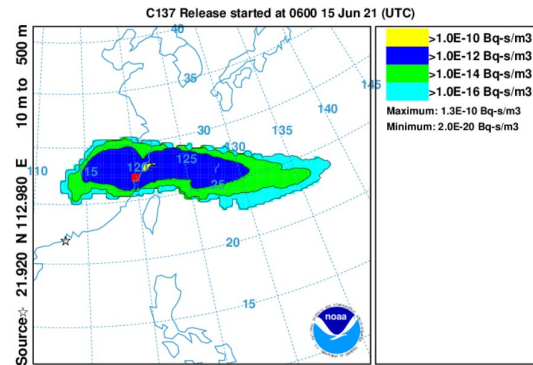
Updated 1:20 PM ET, Mon June 14, 2021



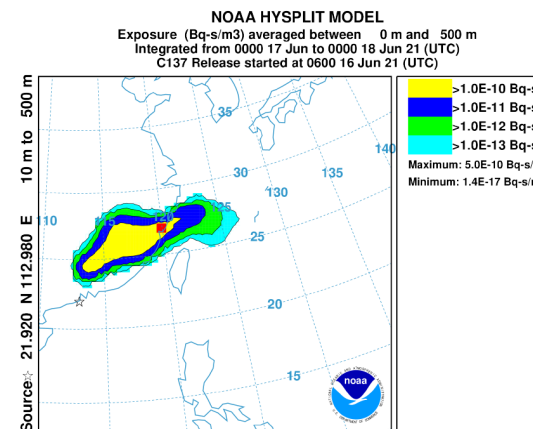
- A total of 20 6-hr releases with unit emissions from Taishan NPP were run through June 27, 2021.
- Four surrogates (Hpar, Lpar, Dgas, Ngas) used.
- Decay and dose calculated in post-processing
- Maps at right are based on unit emissions
- Could be used to estimate actual impacts by multiplying actual estimated emissions



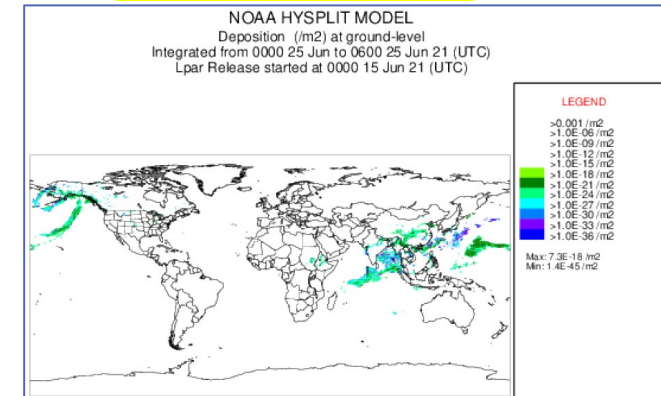
Estimated exposure Jun 17, based on 6-hr unit emission release 0-6Z June 15



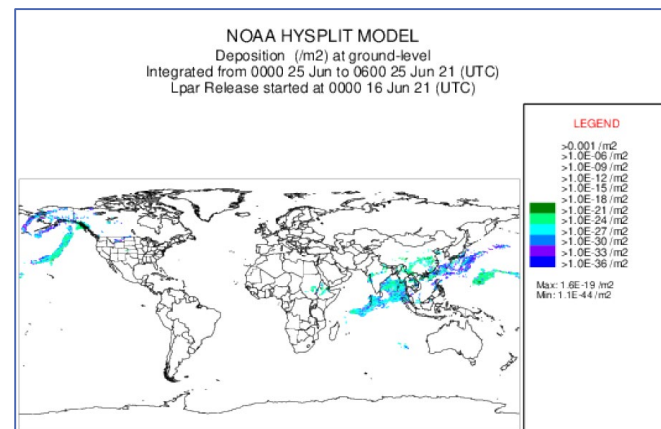
Estimated exposure Jun 17, based on 6-hr unit emission release 0-6Z June 16



Estimated deposition Jun 25 based on 6-hr unit emission release 0-6Z June 15

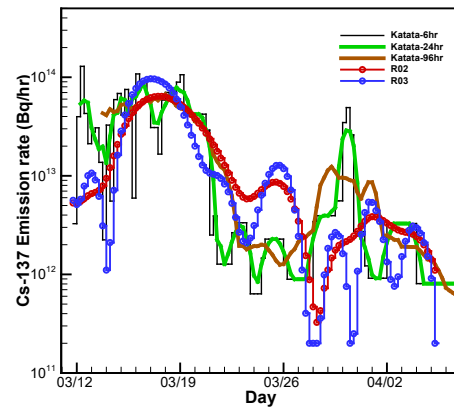
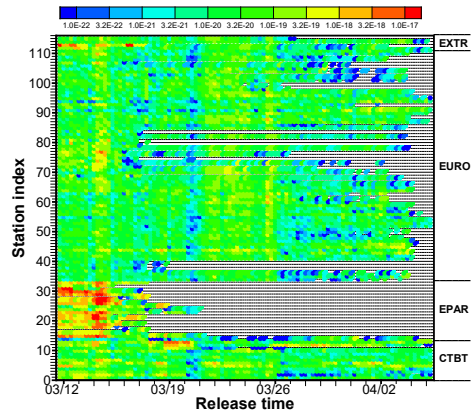
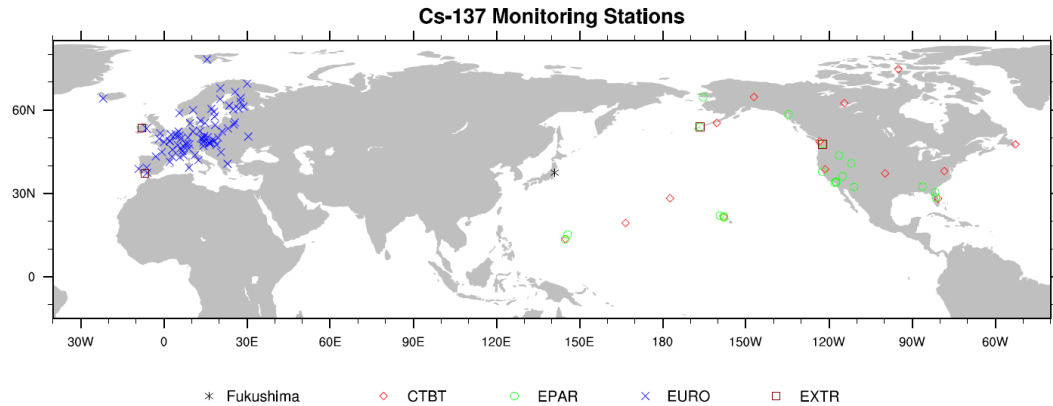


Estimated deposition Jun 25 based on 6-hr unit emission release 0-6Z June 16



Inverse Modeling – From research to future operation

Fukushima accident: Cs-137 Source term estimation using air concentration measurements



Source term estimation using air concentration measurements and a Lagrangian dispersion model— Experiments with pseudo and real cesium-137, T Chai, R Draxler, A Stein – *Atmos. Environ.*, 2015



<https://www.ready.noaa.gov/fdnpppepa-noaa/setsrcfuka.pl>
(Restricted access to NOAA users and registered HYSPLIT users only)



Working with EPA, a web application has been developed.

[ARL Home](#) > [READY](#) > [Transport & Dispersion Modeling](#) > [HYSPLIT Dispersion Model Fukushima Simulation](#)

HYSPLIT Dispersion Model Transfer Coefficient Matrix for Fukushima

Cost Function Solution of the Source-Receptor Matrix

First select your radiological specie and concentration or deposition. Then click Continue.

- I131 gas
- I131 Particle
- Cs137

Choose to view air concentration or deposition.

- Concentration
- Deposition



[ARL Home](#) > [READY](#) > [Transport & Dispersion Modeling](#) > [HYSPLIT Dispersion Model Fukushima Simulation](#)

HYSPLIT Dispersion Model Transfer Coefficient Matrix for Fukushima

Cost Function Solution of the Source-Receptor Matrix

User selectable observations.

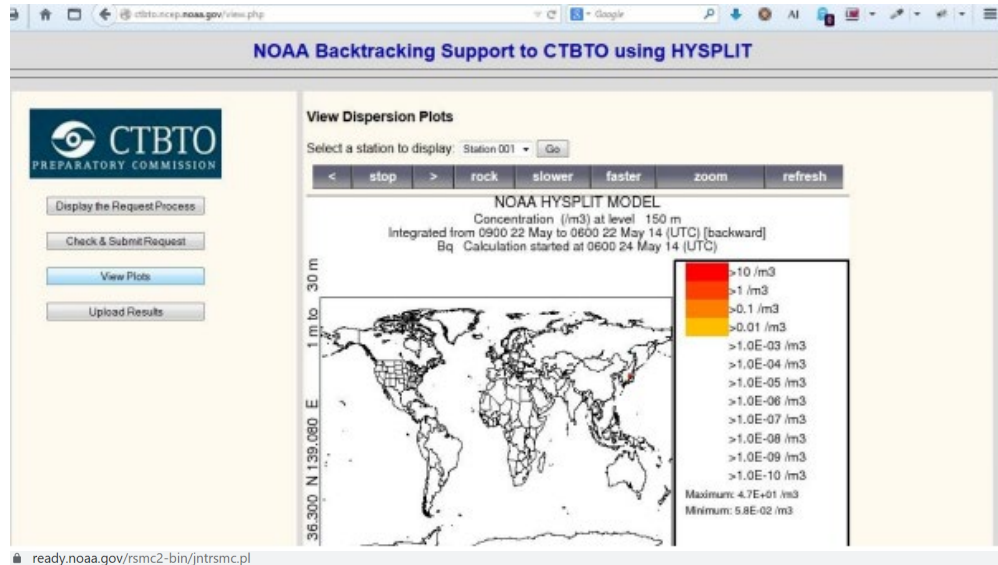
Select stations to use in the cost function calculation. Then click Continue.

STATION ID	CITY	LATITUDE	LONGITUDE	<input checked="" type="radio"/> Use station	<input type="radio"/> Do not use station
001	DUTCH HARBOR	53.9	-166.5	<input checked="" type="radio"/>	<input type="radio"/>
002	JUNEAU	58.3	-134.5	<input checked="" type="radio"/>	<input type="radio"/>
003	NOME	64.5	-165.4	<input checked="" type="radio"/>	<input type="radio"/>
004	MONTGOMERY	32.4	-86.2	<input checked="" type="radio"/>	<input type="radio"/>
005	ANAHEIM	33.8	-117.9	<input checked="" type="radio"/>	<input type="radio"/>
006	SAN BERNARDINO CTY.	34.1	-117.4	<input checked="" type="radio"/>	<input type="radio"/>
007	SAIPAN	15.1	145.7	<input checked="" type="radio"/>	<input type="radio"/>
008	GUAM	13.4	144.7	<input checked="" type="radio"/>	<input type="radio"/>
009	KAHUKU	21.6	-157.9	<input checked="" type="radio"/>	<input type="radio"/>
010	KAUAI	22.1	-159.4	<input checked="" type="radio"/>	<input type="radio"/>
011	BOISE	43.6	-116.1	<input checked="" type="radio"/>	<input type="radio"/>
012	LAS VEGAS	36.1	-115.1	<input checked="" type="radio"/>	<input type="radio"/>



Quality and Performance: Operational Implementations

- The CTBTO on-demand operations was transitioned from ARL to NCEP for operation in September 2014. ARL has provided several updates to the system for the continuous operation (with ~10 requests each year).
- ARL has continued the WMO RSMC monthly exercises with the assistance of NCEP Operation Center (NCO) since its formal operation in 2007 to present. ARL is also assisting NCEP/NCO to build its website at NCO to replace the current ARL website. Time of Arrival (ToA) and TCM products are being developed.



REGIONAL SPECIALIZED METEOROLOGICAL CENTER (RSMC)

TRANSPORT MODEL PRODUCTS

The following are current (as of the date indicated in the table) operational RSMC products as established by **The World Meteorological Organization (WMO)** for the provision of transport model products for environmental emergency response. To view a product click on the text link or click on one or more checkboxes and then click on the **Request checked boxes** button at the bottom of the form. Details on the model products can be found in **WMO/TD-No. 778**. The lead RSMCs are highlighted in yellow shading. To ensure the latest update, refresh/reload your browser.

For all (current and past) model results, click on the link titled, **"All Products"** in the first column of each RSMC. **"No archive"** is displayed if no additional products are available.

RSMC TIME OF MODEL RUN (YYYYMMDDCC_HHMM)	MODEL PARAMETERS	JOINT STATEMENT	VIEW PRODUCTS	TRAJECTORIES	TIME PERIOD 1 +24 HRS	TIME PERIOD 2 +48 HRS	TIME PERIOD 3 +72 HRS
	Cover (Postscript)	Region III/IV	Check All Uncheck All	<input type="checkbox"/> Trajectories (traj.txt)	<input type="checkbox"/> Exposure <input type="checkbox"/> Deposition	<input type="checkbox"/> Exposure <input type="checkbox"/> Deposition	<input type="checkbox"/> Exposure <input type="checkbox"/> Deposition



Quality and Performance: *Publications*

Maurer C., J. Baré, J. Kusmierczyk-Michulec, **A. Crawford**, P.W. Eslinger, Pe. Seibert, B. Orr, A. Philipp, O. Ross, S. Generoso, P. Achim, M. Schoeppner, A. Malo, A. Ringbom, O. Saunier, D. Quèlo, A. Mathieu, Y. Kijima, **A. Stein**, **T. Chai**, **F. Ngan**, S. J Leadbetter, P. De Meutter, A. Delcloo, R. Britton, A. Davies, L.G. Glascoe, D.D. Lucas, M. D Simpson, P. Vogt, M. Kalinowski, T.W. Bowyer (2018). International challenge to model the long-range transport of radioxenon released from medical isotope production to six Comprehensive Nuclear-Test-Ban Treaty monitoring stations, *J. of Environ. Radioactivity*, 192, pp. 667-686, doi:10.1016/j.jenvrad.2018.01.030.

P.W. Eslinger, T. W Bowyer, P.Achim, **T. Chai**, B. Deconninck, K. Freeman, S. Generoso, P. Hayes, V. Heidmann, I. Hoffman, Y. Kijima, M. Krysta, A. Malo, C. Maurer, **F. Ngan**, P. Robins, J.O. Ross, O. Saunier, C. Schlosser, M. Schöppner, B. T Schrom, P. Seibert, **A. Stein**, K. Ungar, J. Yi (2016). International challenge to predict the impact of radioxenon releases from medical isotope production on a comprehensive nuclear test ban treaty sampling station, *J. Environ. Radioactivity*, 157, pp 41-51, doi:10.1016/j.jenvrad.2016.03.001.

Quality and Performance: *Presentations*

- Cohen, M., T. Chai, A. Crawford, H. Kim, C. Loughner, T. McKinney, F. Ngan, A. Ring, and S. Zinn, “The NOAA HYSPLIT Atmospheric Transport and Dispersion Model: Recent Updates and Nuclear Applications”, 2021 International MACCS Users Group (IMUG) Meeting, Sept 20-22, 2021.
- Chai, T., “NOAA' experience in source inversion and radioactivity emergency response problems”, IAEA (International Atomic Energy Agency) Meeting on Sharing Experience in Source Term Estimation and Air Dispersion Modelling for Nuclear Emergency Preparedness and Response, virtual meeting hosted in Beijing, China, July 5-7, 2021.
- Chai, T., “NOAA' experience in the use of HYSPLIT in inverse modelling (with demo)”, IAEA (International Atomic Energy Agency) Meeting on Sharing Experience in Source Term Estimation and Air Dispersion Modelling for Nuclear Emergency Preparedness and Response, virtual meeting hosted in Beijing, China, July 5-7, 2021.
- Chai, T, F. Ngan, and A. Stein, “HYSPLIT Inverse Modeling”, 2019 International MACCS Users Group (IMUG) Meeting, June 10-11, 2019.
- Chai, T, A. Stein, H. Kim, F. Ngan, A. Crawford, B. Stunder, M.J. Pavolonis, and S. Kondragunta, “HYSPLIT Inverse Modeling”, 20th George Mason University Conference on Atmospheric Transport and Dispersion Modeling, Fairfax, VA, USA, June 18-20, 2019.
- Chai, T, F. Ngan, and A. Stein, “Data assimilation and inverse modeling with HYSPLIT Lagrangian dispersion model”, Seventh International WMO Symposium on Data assimilation, Florianópolis, Brazil, Sept 11-15, 2017.
- Stein, A., R.R. Draxler, G.D. Rolph, B. Stunder, M. Cohen, and F. Ngan, “NOAA’s HYSPLIT atmospheric transport and dispersion modeling system: history, applications, and new developments”, 2016 International MACCS Users Group (IMUG) Meeting, Sept 2016.



Future Plans

CTBTO On-demand Operation and RSMC Emergency Response activities

- Continue to support NCEP/NCO for CTBTO and RSMC operations;
- Implement HYSPLIT updates;
- Port to WCROSS2, the new operational and R&D high performance computing system;
- Implementation of TCM approach for the RSMC products;
- Assist other RSMCs to implement the TCM approach;
- Pending NCEP/NCO decision, convert CTBTO operations from NCO intranet to WCROSS application.

Research and development

- Continue to develop and improve the HYSPLIT-based inverse system for source term estimation
- Revisit the Fukushima accident case for inverse modeling using near-source measurements
- Work with US EPA to continue the development of source term estimation website
- Continue participating in model intercomparisons of the long-range transport of radionuclides, including the ongoing “Radioxenon Nuclear Explosion Signal Screening Inter-Comparison Exercise 2021”
- Test ensemble runs to quantify the uncertainties in HYSPLIT dispersion results
- Include uncertainties to the source term estimation results
- Explore machine-learning techniques for better source term estimation

